Ontario

Ministry of
Transportation and
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Minister
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Engineering
Division

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EM-70

Provincial Highways

Segregation Study Part I (Evaluation of Delivery and Road Sampling) Granular Materials

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Soils and
Aggregates
Section

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1 Executive Summary

The Ontario Ministry of Transportation and Communications had decided that, in connection with the development of quality assurance specifications for granular materials, it would adopt point-of-use sampling. Part I of this study was initiated to evaluate the reliability of sampling granular aggregates at two point-of-use locations, namely, on the road and at the stockpile as the material is loaded. In particular, the study was devised to determine if significant segregation and breakdown of material would occur between these two points of sampling due to the loading, hauling and placement operations.

The field studies were conducted in the 1982 construction season on five contracts which encompassed the variety of production, stockpile construction and placement methods commonly used for granular materials in Ontario. On each contract, approximately 30 samples were obtained at each location of sampling by random sampling methods which were devised for this project. The evaluation consisted of statistical analysis and comparisons which are fully described in the report.

The findings indicated that no significant segregation or breakdown occurred between the two points of sampling investigated. Analysis of supplementary data available from the field studies indicated that, in some cases, samples obtained as the stockpile was built did not compare with either road or delivery samples. However, an in-depth study will be made in 1983 to examine the relationship between samples obtained as material is put into stockpile as compared to samples obtained as material is taken out of stockpile. This report will be published in 1984 as "Segregation Study, Part II (Evaluation of Stockpile and Delivery Sampling) Granular Materials".

2 Introduction

In connection with the new acceptance procedures for granular materials, it has been determined that sampling of the aggregates would be carried out as close as possible to the point-of-use. Under Special Provision No. 331, dated August 1983, four acceptable locations for sampling have been identified, namely: (a) at the source during production, (b) from existing stockpiles, (c) from the material as it is being loaded on delivery trucks, and (d) from the roadway.

Since samples may be taken at delivery as well as on the road, it is important to know if there is a significant variation of gradation as a result of material segregation or breakdown between these two points of sampling. The question the project supervisor must answer is this: "Can I be sure that an acceptable lot of material that was randomly sampled at the point of loading would also be within specifications after it was placed on the road?" For the aggregate producer who wishes to carry out process control sampling at delivery, it is even more important to be certain that the lot of material found to be acceptable will remain within specification when properly placed and sampled on the road.

Our main concern in this study has been to determine whether changes in gradation resulting from loading, transporting and placing of the aggregates can be so significant that a lot which was acceptable at loading will be outside the specification on the road.

In order to study, analyze and evaluate the variations in gradation between different points of sampling of granular material, a comprehensive field sampling and testing program was designed. The program was implemented in five M.T.C. contracts during the summer of 1982.

This report contains an explanation of the methodology, description of the five field studies, and the evaluation of test results, together with conclusions and recommendations for improvements in sampling and testing procedures.

3 General Outline of the Studies

3.1 Sampling and Testing

At each contract, samples of Granular A were taken at the location and time of loading the trucks from the stockpiles (delivery samples). These samples were taken by having the front end loader dump a bucket of material to be loaded, then backblading it level to half the height of the dumped load. The technician, using a modified tile spade for sampling purposes, then took five or six shovel-fulls at random locations or diagonally across the levelled area (approx. 2 m x 2.5 m). MTC sample bags were filled to the indicated fill line representing an approximate field sample size of 25 kg. (Figure 1).

Sampling times were determined by use of random number tables.

Sampling and testing on each contract was performed by the aggregate producer's technician, in accordance with the MTC guidelines. Since sampling was done at the last point before the material left the producer's plant, these may also be considered to be "quality control" tests.

FIGURE 1 - Obtaining a Delivery Sample

A second set of samples was obtained at each contract from the road. Samples were always taken after the truck load was placed and spread, but before compaction. Sample locations were determined by use of two random numbers, representing the longitudinal and transverse direction of the spread. The sample was collected within an area equal to the size of the MTC sample bag, to the full depth of layer (Figure 2). Delivery samples were tested by

the producer's technicians in their own laboratories, while road samples were delivered to the MTC field laboratories, and tested by Ministry personnel.

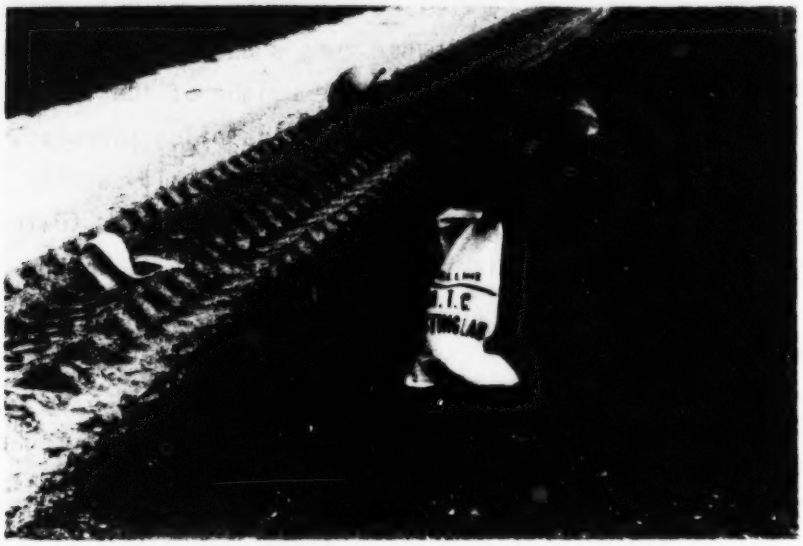


FIGURE 2 - Obtaining a Road Sample

All the samples were routinely split into two test portions by use of a sample splitter.

In order to determine if, under normal handling operations, a change in apparent material gradation would occur between the point of delivery and road sampling, it was necessary to compare the test results on both sets of samples. Since different personnel and laboratories were involved in the sampling and testing of the road samples and the delivery samples, it was realized that differences in the two sets of data could be the result of sampling and testing variances, as well as changes in material gradation. Sampling variances were minimized by adopting random sampling techniques. In order to eliminate the testing variance, the split portions of the field samples were tested in the Downsview laboratory. The results of Head Office testing were used to determine if significant segregation or breakdown occurred. In addition, the Downsview results were compared with the field results, in order to gain an appreciation of the testing variance.

On each job, at least 30 samples were taken at delivery, and the same number of samples on the road, so that statistical data computed on the samples could be assumed to be population parameters.

3.2 The Statistical Evaluation of Aggregate Segregation and Breakdown

Segregation is a result of the sorting of materials. Portions of a well mixed material may become finer as the coarse particles are dislodged or displaced. As this happens, other portions or areas may become much coarser. The effect shows up in the results of gradation tests on random samples. As sorting or segregation occurs, the results of gradation tests will indicate that the material has a wider variation or a greater difference in the gradation of individual test results. This will effectively result in *an increase in the lot range. Since range is one of the acceptance criteria in the specification, it is obvious that range must be controlled.*

Since there is a mathematical relationship between the range and the standard deviation, an increase in the lot range will increase the value of the standard deviation and the variance. To determine whether segregation will have any significance on the acceptability of the material, the material variability indicated by delivery samples was compared to the material variability indicated by road samples.

In order to compare material variability, the statistical method known as hypothesis test of variance was employed. In this method, a ratio of the variance results of delivery samples to the road samples is calculated. This ratio is then compared with the applicable statistical value to determine whether the two sets of data represent the same population. It is not within the scope of this report to detail this statistical method used. Interested readers can refer to any basic statistics text book (1). It should, however, be noted that statistical analyses were carried out at a significance level of $\alpha = 0.05$ or a confidence level of 95%, for each project.

The handling, transporting and placing of material may result in a breakdown of some of the weaker aggregate pieces. This may result in a change in material gradation. The coarse particles tend to break into finer pieces, resulting in a finer overall material. Gradation tests would indicate that *the lot mean gradation becomes finer, perhaps too fine to meet the acceptance criterion.*

Generally speaking, granular materials that have met the physical requirements for Granular A should not break down significantly under the handling, transporting, placing and spreading operations.

To evaluate the possibility of breakdown, a further analysis was carried out to determine if the mean or average gradation of delivery samples is different from the mean gradation of road samples. This analysis employed the statistical method known as hypothesis test of the mean. For this method, the difference in population means is expressed in units of the standard error of the means. This value is then compared with the applicable statistical value to determine whether or not the difference in means can be attributed to a breakdown in the material.

It is important to note that, in carrying out the statistical hypothesis test of means, an α (alpha) risk of 5% was chosen. This is also known as a Type I error of rejecting the assumption that the two means are from the same population when, in fact, they are.

3.3 Precision and Accuracy of Test Results

It was originally thought that the evaluation of segregation and degradation could be accomplished by comparisons of the test results obtained by the field laboratories on the delivery and road samples. Field experiences during the early part of the study indicated that this method of evaluation was not appropriate, since delivery and road samples were generally tested in different laboratories that exhibit different biases. In order to gain a better appreciation of the bias of the individual laboratories, the Downsview laboratory test results on the sample splits were compared with the test results on the same sample obtained by the field laboratory. The methods of comparisons used were the tests of hypothesis, as already described, employed in this instance to determine the precision and accuracy of the various laboratories and technicians involved. The accuracy of the test results indicates how close the average of the results are to the true mean value. Precision of the test data is a measure of the scatter of individual results. Any set of test data which is precise will be consistently higher (or consistently equal to or consistently lower) than the true mean value. If the data is not precise, then the individual results will exhibit a wide variation being sometimes lower, sometimes higher, and sometimes equal to the true mean value. Regardless of the precision of a set of data, the accuracy may be good or poor, depending on how close the average of the individual values are to the true value.

A good illustration of precision and accuracy is given by Hudson (2) in an example of a marksman shooting at a target. This analogy is shown in Figure 3, and needs no further explanation.

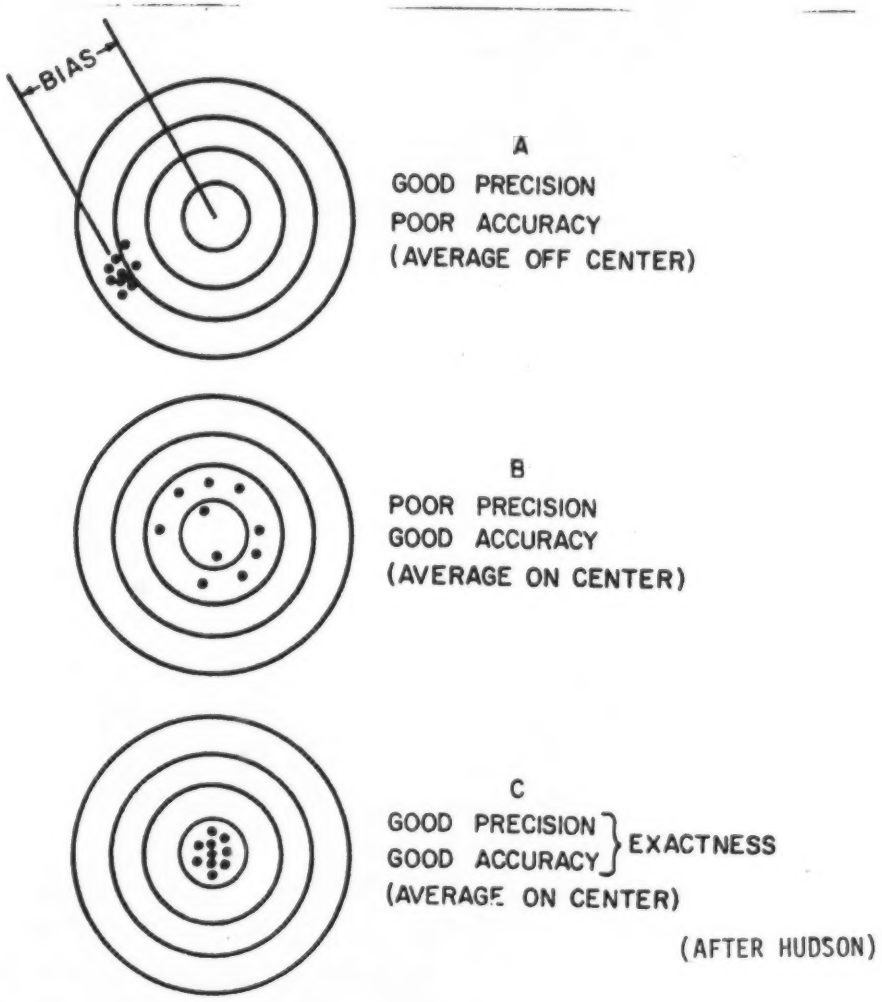


FIGURE 3

The hypothesis tests of the mean were used to determine the different levels of accuracy of the test data, whereas the degree of precision of these tests were evaluated by means of the hypothesis tests of variance.

4 Contract No. 81-102; Hwy. 402; Southwestern Region

4.1 Production and Construction Data

The Granular A aggregate for this contract was produced from Vanderburgh Pit, Komoka, Ontario, a medium size licensed gravel pit, owned and operated by Huron Gravel Ltd., Chatham, Ontario. After crushing, the material was hauled by trucks to the stockpile. The stockpile was built by trucks in layers, roughly 1.5 m thick, each layer being levelled off by bulldozers. Since the Granular A was used for shouldering only, the maximum size was specified to be 22.4 mm. The total tender quantity of the aggregate was 91 000 tons.

The aggregates were loaded from the stockpile into delivery vehicles by a front end loader (Figure 4). The delivery vehicles were of the bottom discharge type, having about 34 to 38 t capacity. The haul distance was 14 to 30 km, on paved county roads. The vehicles travelled at an average speed of 80 km/h.

The material was placed on the finished pavement by bottom discharge trucks, and bladed onto the shoulder area by graders.

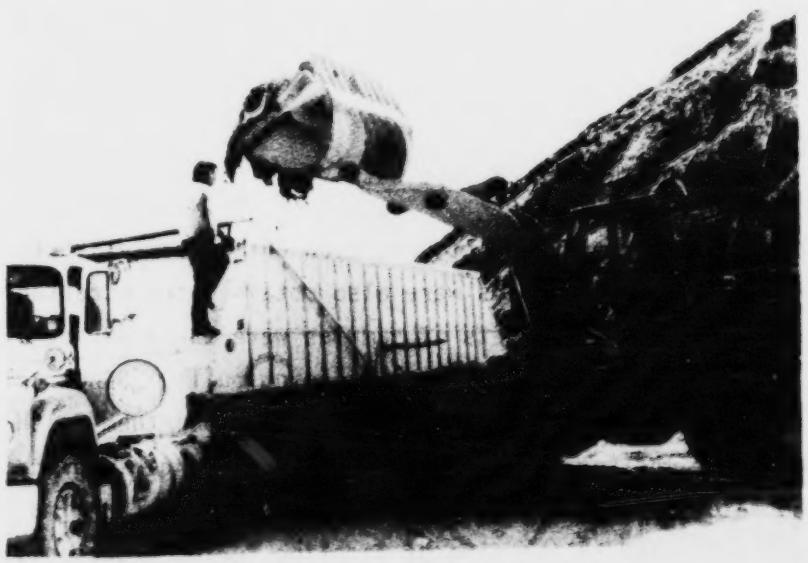


FIGURE 4 - Delivery Vehicle Being Loaded

4.2 Sampling and Testing Program

A total of 32 samples were obtained at two locations, first when the trucks were loaded and second, on the road. Delivery samples were obtained by a technician from Huron Gravel Ltd., who also performed the gradation tests in Huron's laboratory, located in a trailer at the gravel pit. Tests were done by sieving the coarse aggregates through a series of 300 mm (12") diameter sieves, shaken by hand, using a rocker box. The fine portion was always washed and also hand shaken through 200 mm (8") diameter sieves. The average mass of the test portion was 4.8 kg.

Road samples were obtained by an MTC student technician, who was trained and guided by senior personnel of this office. Samples were always taken from the same truck that had been sampled at delivery.

Road samples were tested in the MTC field laboratory by the student technician. The laboratory was located at the pit next to the producer's testing laboratory. Sieving of the coarse aggregate was done by a Gilson mechanical shaker, while the fine portion was sieved using a CSC-Meinzer sieve shaker. A shaking time of 8 minutes was maintained. The average mass of the test portion was 5.2 kg.

As mentioned earlier, all the samples (delivery and road) were split in half, the second half being delivered and tested in the Head Office laboratory, located at Downsview.

4.3 Analysis and Evaluation of Test Data

Prior to the study, Huron Gravel Ltd. carried out an extensive testing program for process control. Samples were also obtained for acceptance testing by Ministry personnel. Both sets of samples were taken during aggregate production, at the stockpile, while it was being built. Since all these test results were available, it was decided to include them in the study in order to determine whether there was any apparent change in gradation from the time the material was sampled during stockpiling to the time it was sampled during loading and to the time of sampling during placement.

The analysis reported is based on more than 230 test results, broken down to sets of tests as follows:

1. Process control tests carried out by Huron Gravel Ltd. during production of the material (88 tests).

2. Acceptance testing carried out by MTC during stockpiling of the material (20 tests).

3. Delivery samples obtained by Huron Gravel Ltd., and tested by their technician in their laboratory (32 tests).

4. Delivery sample splits obtained by Huron Gravel Ltd., and tested by our Downsview laboratory (32 tests).

5. Road samples obtained and tested in the field laboratory by an MTC technician from the Soils and Aggregates Section (32 tests).

6. Road sample splits obtained by the Soils and Aggregates technician, and tested by our Downsview laboratory (32 tests).

The gradation test results were summarized for each of the six sets of data by computing the mean and standard deviation of the percentage passing each of the specification sieves. This data is presented in graphical form on Figures 5 to 10 inclusive for the 16 mm, 9.5 mm, 4.75 mm, 1.18 mm, 300 um, and 75 um sieves respectively. This graphical form is a normal distribution curve drawn to scale, showing the mean and dispersion of the individual test results ($\bar{x}$ & σ). For those more familiar with a gradation chart display, the mean of the six individual sets of data is plotted on the gradation chart (Figure 11).

It should be quite obvious, upon examination of the data, that there are differences in the results obtained. In order to determine whether or not these differences are significant, a systematic statistical analysis was performed, as was outlined under Sections 3.2 and 3.3. The results of the analysis can be expressed in appropriate statistical statements or conclusions. These conclusions will be presented for each set of tests, with some explanations for those readers not fully familiar with statistical terminology.

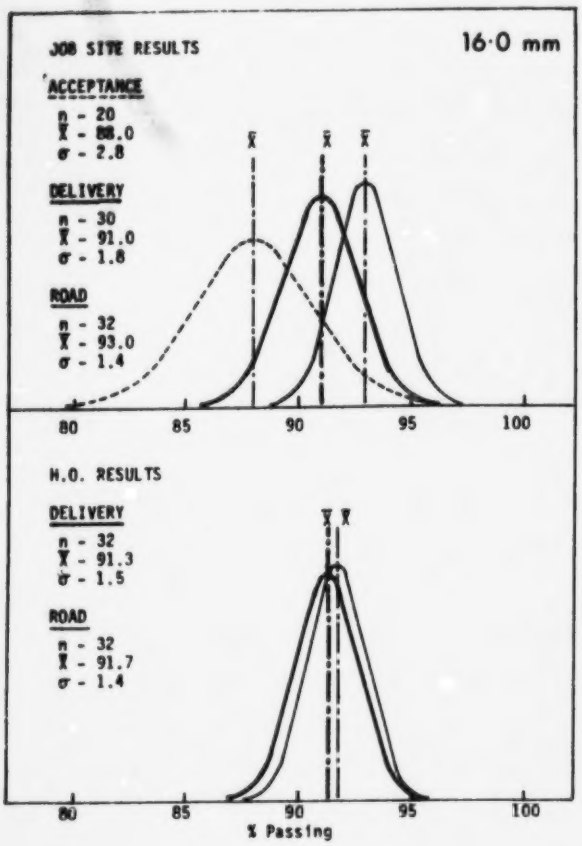


FIGURE 5

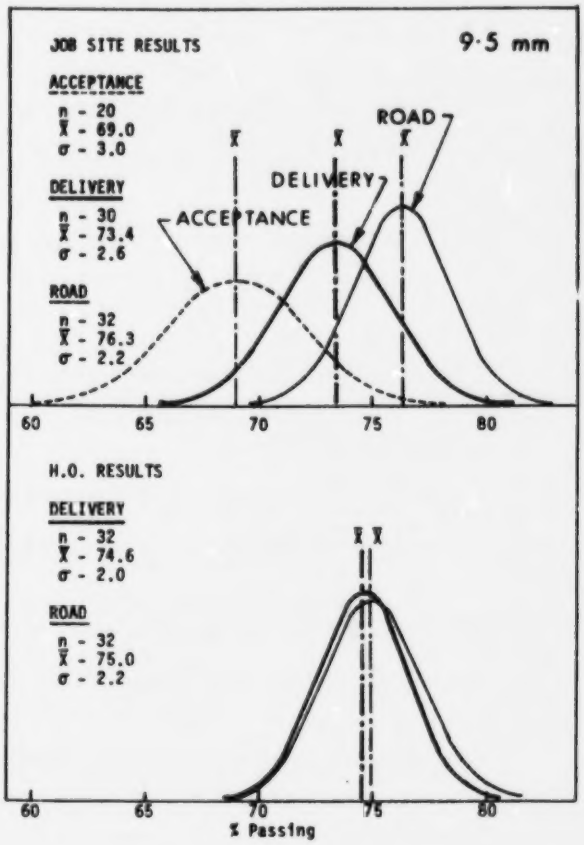


FIGURE 6

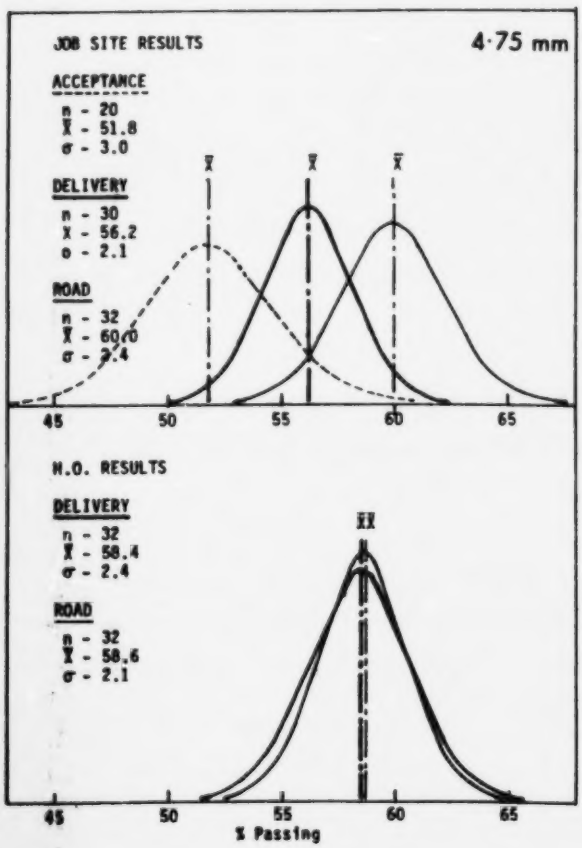


FIGURE 7

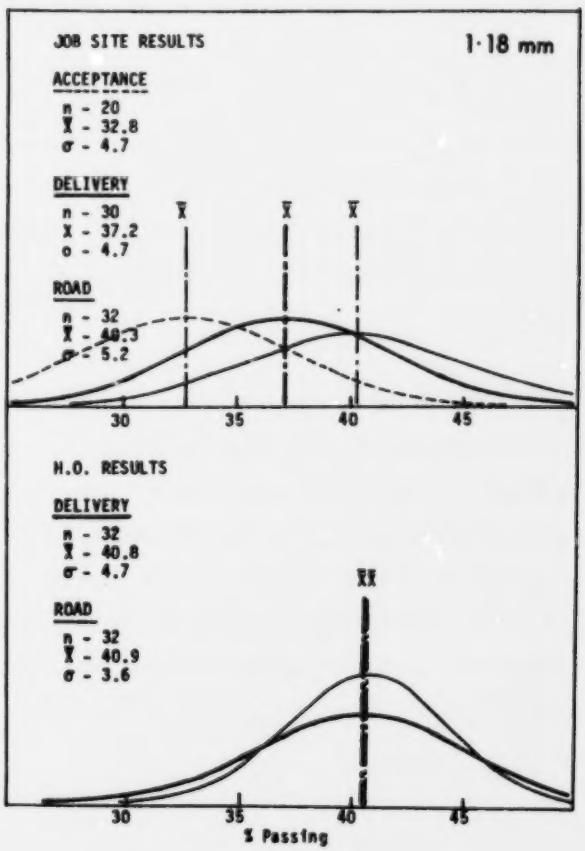


FIGURE 8

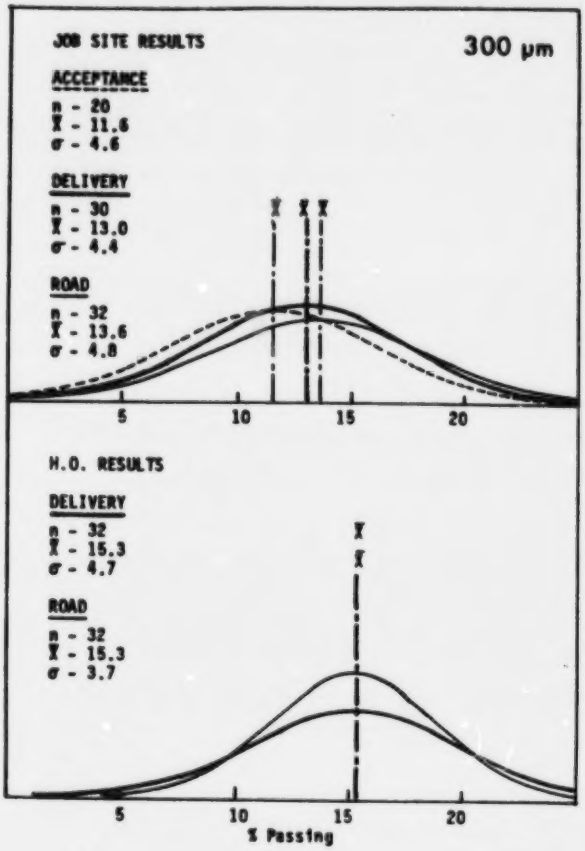


FIGURE 9

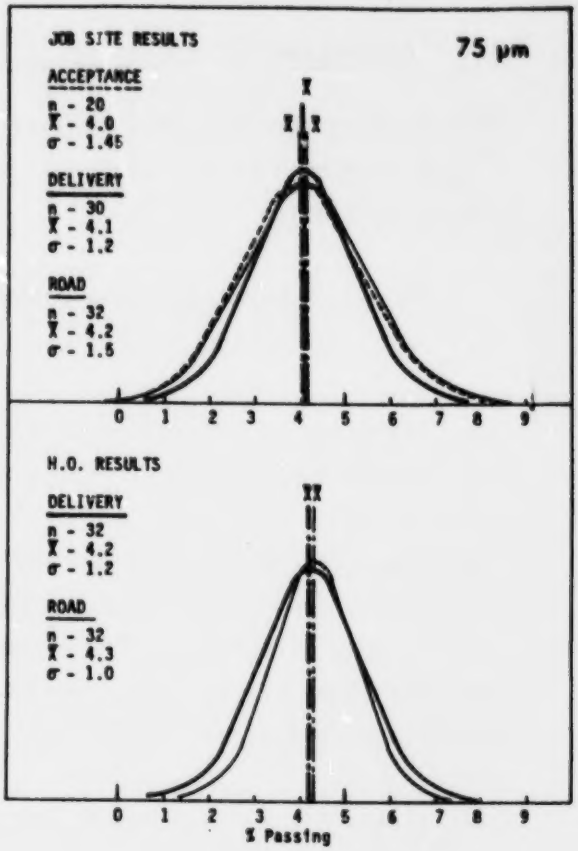
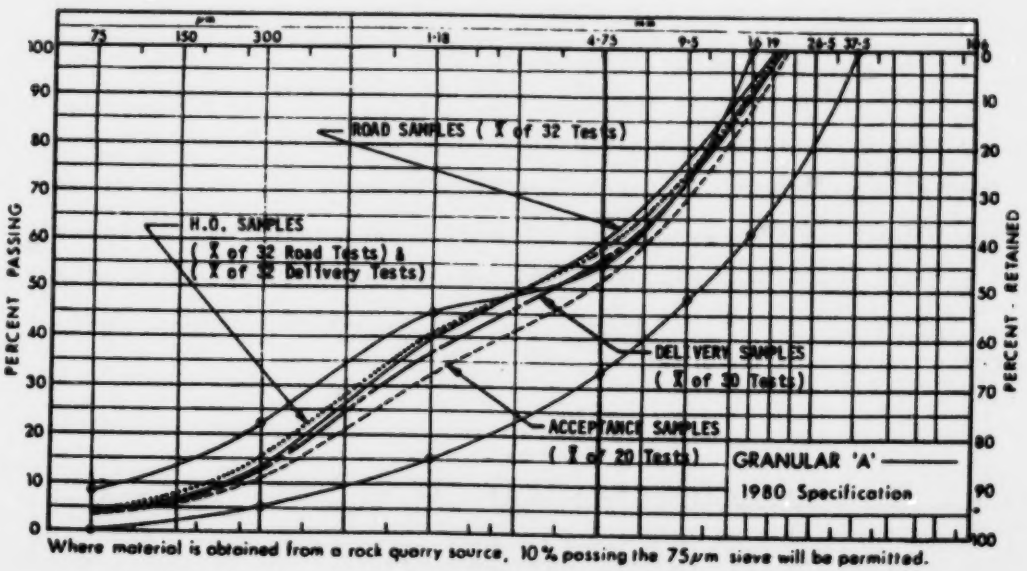


FIGURE 10

GRADATION SUMMARIES



Where material is obtained from a rock quarry source, 10% passing the 75µm sieve will be permitted.

FIGURE 11

4.4 Conclusions of the Analysis

In comparing the test results obtained by our Downsview laboratory on delivery samples with those of road samples, the analysis resulted in the following conclusions:

- There was no significant difference in the variance of the delivery sample gradation and the variance of road sample gradations.

- There was no significant difference in the mean gradation test result obtained by delivery samples versus that obtained by road samples.

These two statements, in fact, indicate that there was no significant segregation or breakdown of the material between the point of delivery and after being placed on the road. Consequently, where appropriate sampling and testing techniques are employed, gradation test results will be valid, whether sampled at delivery or on the road.

Comparisons of the test results obtained by the Downsview laboratory and those obtained by the two field laboratories are described as follows:

Field Laboratory Huron Construction Ltd. Compared with Head Office Laboratory

A comparison of the test results obtained by these laboratories on the delivery samples indicates that both have the same degree of precision. The degree of accuracy was the same for both laboratories on the 16 mm and 75 um sieve only. On all other sieves, the degree of accuracy was different. Huron Construction's laboratory consistently showed a much coarser aggregate than the Downsview laboratory. This discrepancy is partly attributed to the different equipment used. Our laboratory used mechanical shakers, whereas Huron's field laboratory employed hand sieving techniques. It is probable that the hand sieving method produced a less effective sieving action, hence indicating a coarser material.

M.T.C. Field Laboratory Compared with Head Office (Downsview) Laboratory

A comparison of the test results obtained by these laboratories on the road samples indicates that the degree of accuracy on the coarse aggregate sieves was different. The results of the field test indicated a finer aggregate than that indicated by Downsview testing. The degree of precision was the

same except on the 1.18 mm and 75 um sieves where the field laboratory indicated greater variation than the Downsview laboratory. These discrepancies are not readily explainable; they may have been the result of the condition of the sieves used or possibly the result of an inexperienced operator.

4.5 Auxiliary Data on Stockpile Samples

As mentioned earlier, Huron Gravel Ltd. carried out an extensive process control sampling program (88 tests), while the stockpile was being built. Acceptance sampling by the Ministry was also performed at the same time and location (20 tests). While not strictly within the scope and objectives of these projects, analysis and comparison of these two sets of data were also done using the statistical methods of hypothesis testing.

The analysis indicates that the two sets of test data gave excellent agreement on the coarse aggregate sieves. On the fine aggregate sieves and, in particular, on the 300 um and 75 um sieves, the results differed substantially. The producer's testing indicated consistently less percentage passing these sieves. This is attributed to the fact that the producer's test procedures did not include washing the fine aggregate.

By comparison of the delivery, road and stockpile (acceptance) samples, some further insight into the relationship of the various sampling methods can be obtained. The gradation test data on the designated sieves for these tests are summarized in the following table:

DESIGNATED SIEVE	MEAN % PASSING DESIGNATED SIEVE	
	DELIVERY AND ROAD SAMPLES	STOCKPILE (ACCEPTANCE) SAMPLES
16 mm	91.5	88.0
9.5 mm	74.8	69.0
4.75 mm	58.5	51.8
1.18 mm	40.9	32.8
300 um	15.3	11.6
75 um	4.2	4.0

By examining the average percentage passing each designated sieve for two sets of data, it is readily apparent that significant differences exist. The explanation for these marked discrepancies can possibly be attributed to either the method of sampling used which involved sampling from the surface of the truck-dumped material as the stockpile was being constructed or an inadequate sieving effort.

5 Contract No. 82-03; Hwy. 401, Central Region

5.1 Production and Construction Data

The supplier of Granular A for this contract was TRT Sand and Gravel, a large commercial producer, located on Durham Regional Rd. No. 20.

Crushing of the aggregates was carried out by a Pioneer portable crushing unit. After crushing, the material was stockpiled by use of conveyor and stacker, the coned material being levelled off into approximately 1.5 m lifts by a D-7 bulldozer.

A 22.4 mm maximum size Granular was produced for this contract as the material was used for widening, shouldering, and some new construction. Total tender quantity of Granular A required was 101 000 tons.

The aggregate was loaded from the stockpile by a front end loader into the delivery vehicles. The delivery trucks were of the bottom discharge type, having a capacity of 27 to 36 t.

The haul distance was some 23 km to 30 km, 5 km on gravel roads, the remainder on paved highways.

The material was placed and spread on the finished grade by the delivery trucks (Figure 12).

FIGURE 12 - Delivery truck placing load at job site

5.2 Sampling and Testing Program

A total of 31 delivery samples were obtained as the trucks were being loaded, and a total of 31 road samples were obtained from the road after the material had been placed, but before compaction. All the delivery and road samples obtained were split in half, the second half being tested in the Head Office laboratory at Downsview.

Delivery samples were taken by TRT's technician, who also performed the gradation tests in TRT's own laboratory. Washing procedures were carried out for all fine aggregate samples, Figure 13. The well-equipped laboratory had a Gilson mechanical shaker for coarse aggregates and a Tyler portable mechanical shaker for fine aggregates. The average mass of test portion was 7 kg.

FIGURE 13 - Washing procedures being carried out by TRT's technician

Road samples were obtained by MTC personnel from the same truck load that a delivery sample was taken. Road samples were tested in MTC's field laboratory, which was equipped with mechanical shakers, water supply, air conditioning, etc. The average mass of test portions was 7.4 kg.

One of the valuable lessons learned from the previous project (Cont. 81-102) was a recognition that test results from stockpile samples may not represent the gradation of the aggregate on the road. Some acceptance testing on this contract was also done at the stockpile, according to the 1980 guidelines, and it was decided to analyse these tests as well. Some 85 acceptance test results were available, so that reliable statistical parameters could be obtained on the large number of data.

5.3 Analysis and Evaluation of Test Data

Statistical analysis and comparison was again performed by hypothesis testing on the five sets of samples as listed below:

1. Stockpile samples obtained while the pile was being built - sampled and tested by MTC (85 samples) (used for acceptance).

2. Delivery samples obtained by T.R.T., and tested in T.R.T.'s laboratory (31 samples).

3. Delivery samples obtained by T.R.T. - sample split-tested in M.T.C. Downsview laboratory (31 samples).

4. Road samples obtained by M.T.C., and tested in M.T.C. field laboratory (31 samples).

5. Road samples obtained by M.T.C. - sample split-tested in M.T.C. Downsview laboratory (31 samples).

All the test results are presented again by normal distribution curves for each designated sieve (Figures 14 to 19 inclusive). Figure 20 shows the mean gradation of the sets of tests on a gradation chart.

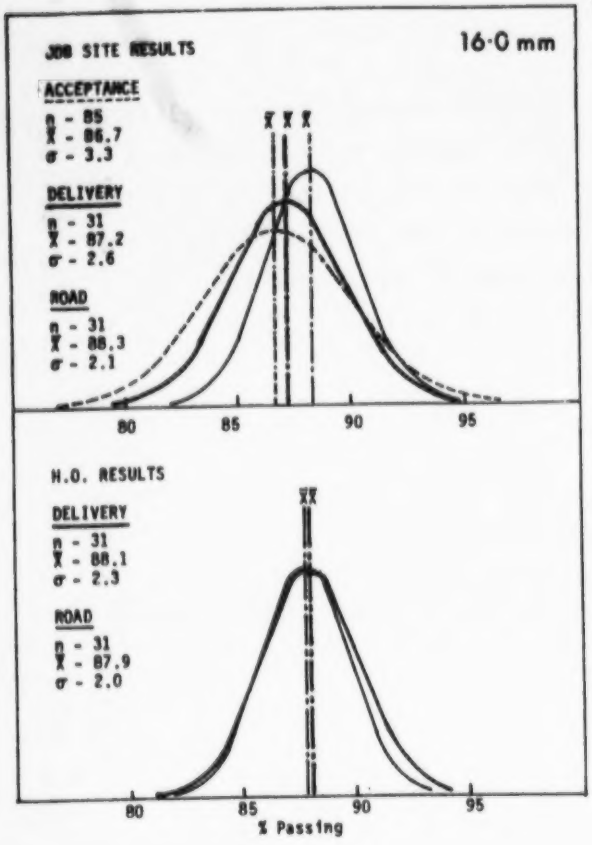


FIGURE 14

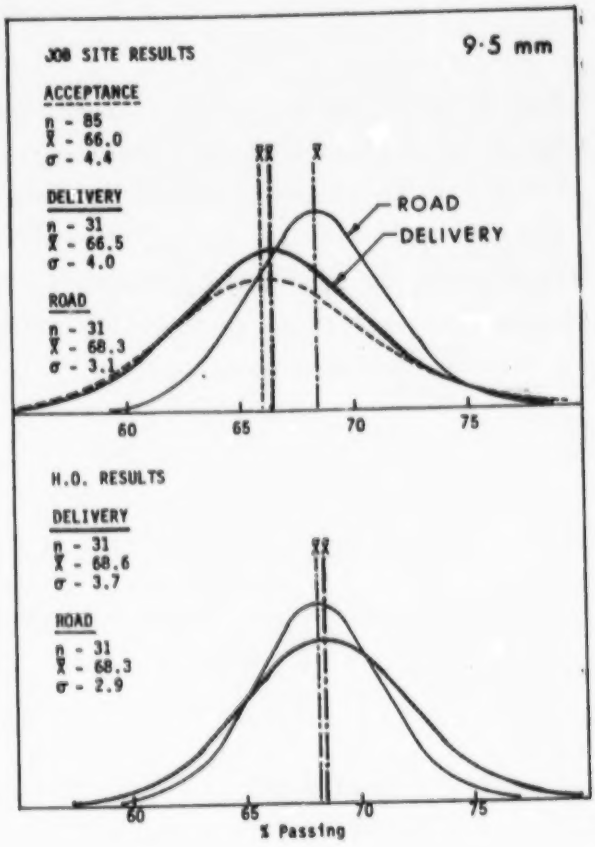
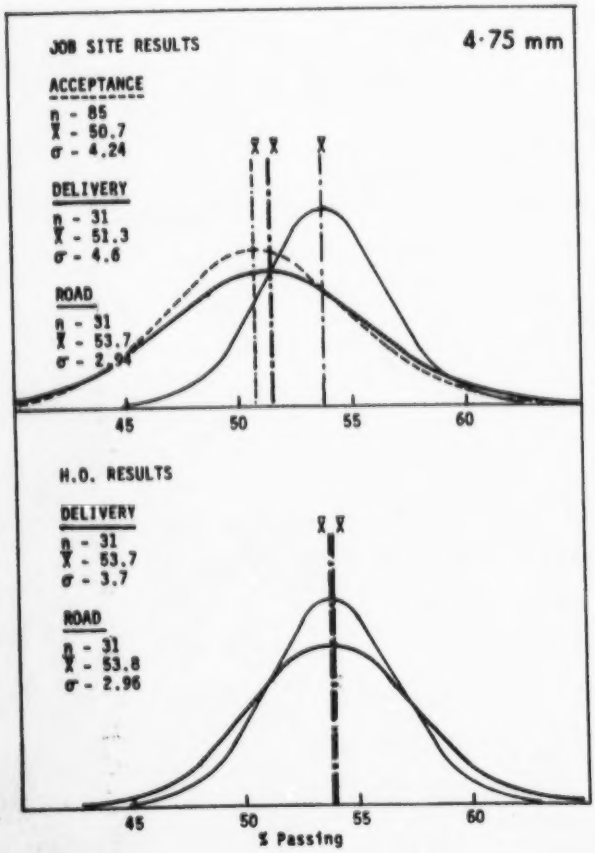


FIGURE 15



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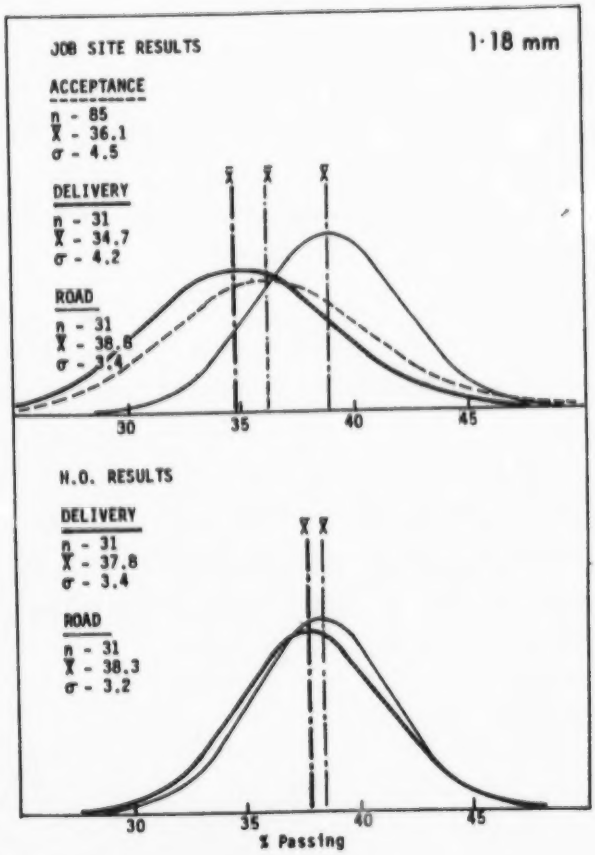


FIGURE 17

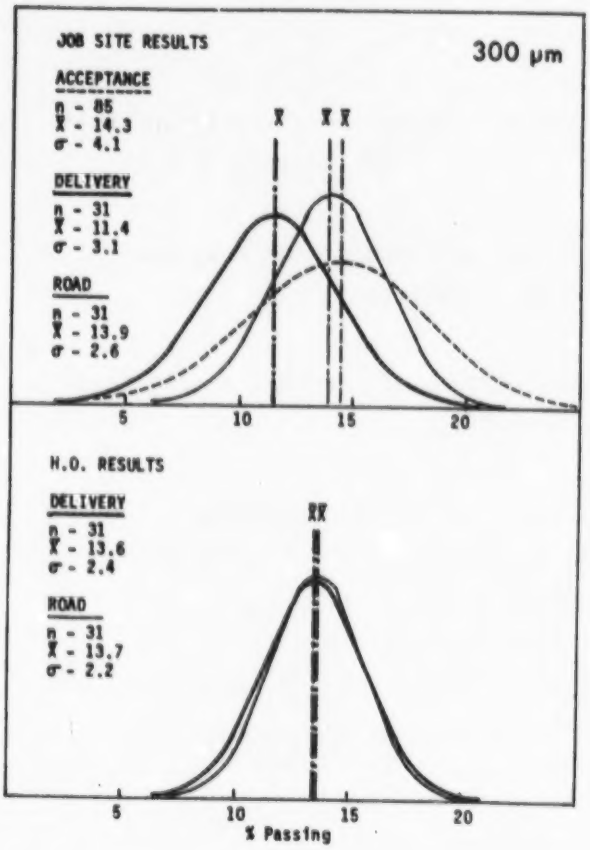


FIGURE 18

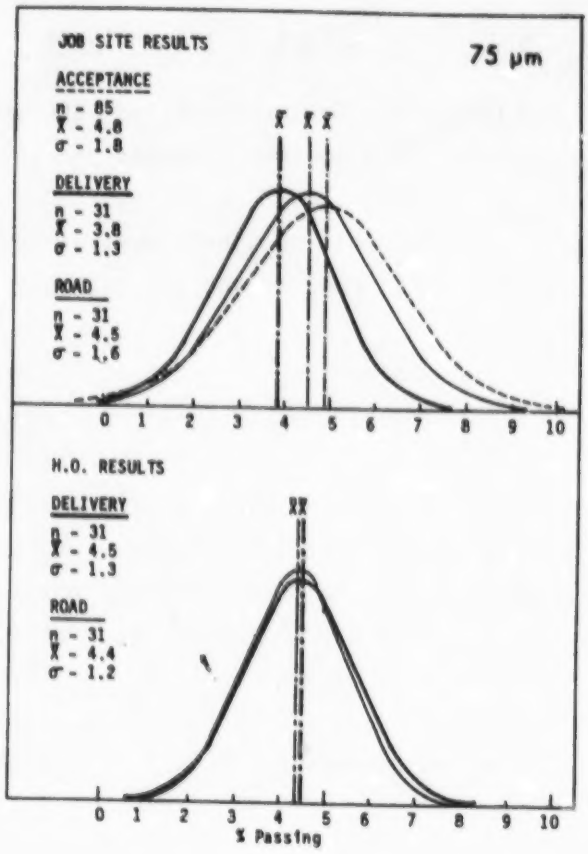
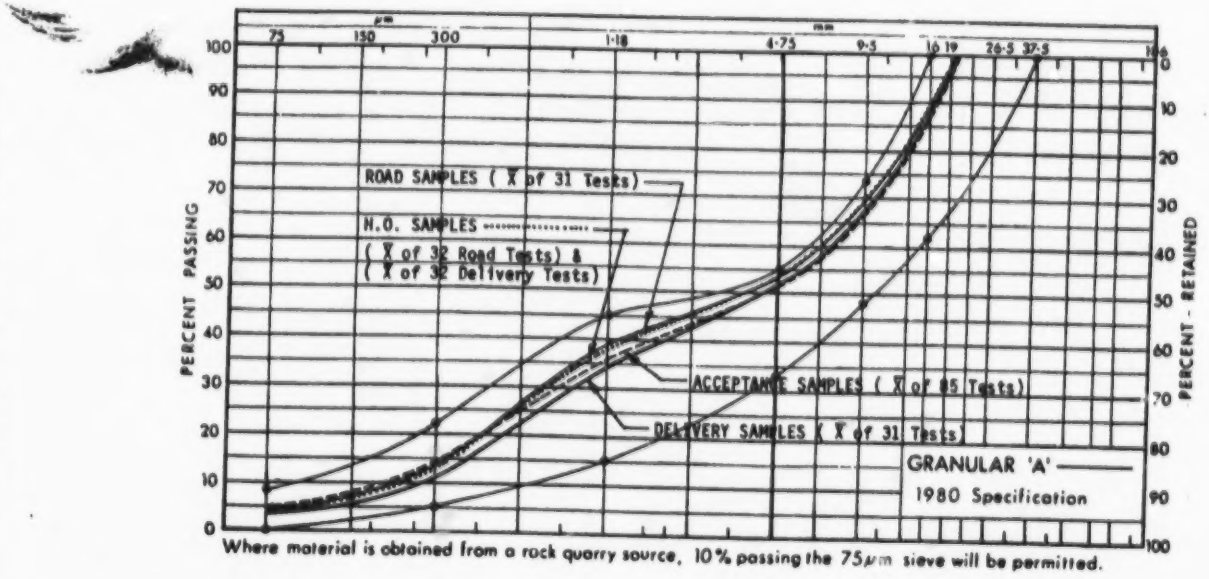


FIGURE 19

GRADATION SUMMARIES



Where material is obtained from a rock quarry source, 10% passing the 75µm sieve will be permitted.

FIGURE 20

5.4 Conclusions of the Analysis

A comparison of the Downsview laboratory test results on the delivery and road samples lead to the following conclusions:

- There is no significant difference in the variance of the road sample test results and the delivery sample test results.

- There is no significant difference in the mean of the road sample test results and the delivery sample test results.

These two conclusions indicate that there is no significant breakdown or segregation between the points of loading from the stockpile and placing on the road. It is to be noted that, generally speaking, the dispersion of the test results are somewhat less for road samples than for delivery samples. Although this difference, according to analysis, is relatively insignificant, the implications are that some slight further mixing (that is de-segregation) has occurred between the point of loading from the stockpile and placing on the road.

A comparison of the test results obtained on the road samples by the Downsview laboratory and the M.T.C. field laboratory indicated both laboratories had the same degree of precision and accuracy. Similar comparisons on the delivery samples indicated the same degree of precision, but different accuracies between the Downsview laboratory and the T.R.T. laboratory. The T.R.T. laboratory indicated a consistently coarser material than indicated by the Downsview laboratory. This discrepancy is attributed to an excessive loss of fines during during T.R.T.'s coarse aggregate sieving operation. Corrective action has been implemented.

6 Project No. 3, Central Region

6.1 Production and Construction Data

Granular A for this project was supplied by a quarry source located in the Central Region of Southern Ontario. At present, the product is being quarried from two levels using traditional techniques.

The blasted rock is loaded by a 13 m^3 diesel electric front end loader into 68 t haul trucks that dump the rock into a primary crusher. The rock is initially reduced to minus 150 mm (6 inch), and further reduced to a minus 63.5 mm (2.5 inch) size. The crushed rock is transported by conveyor belts to various quarry operations.

A 22.4 mm maximum size granular A was produced by a screening process. The coned material was removed by a front end loader, mixed up, and stockpiled for MTC use. The granular A used during the latter part of the contract was supplied from the new aggregate plant. The material was stockpiled by a stacking conveyor. This material was also reworked and mixed up by a front end loader prior to stockpiling for MTC use. The total tender quantity of Granular A was 40 500 tons, and was used mainly for widening and shoulder work. The delivery trucks were loaded from the stockpile by front end loaders owned and operated by the aggregate producer. The material was placed and spread at the contract by tailgating and spreading boxes.

The haul distances to the contract were minimal, being 0.5 to 6.5 km, and haulage was confined to the quarry roads and paved highway.

6.2 Sampling and Testing Program

A total of 35 delivery samples were obtained as the trucks were being loaded, and a total of 40 samples were obtained from the road after the material had been placed, but before compaction. Road samples were obtained the same day as the delivery samples, but not necessarily from the same truck load. Delivery samples were taken by the producer's technician, who also performed the gradation tests in his own laboratory, located on the quarry premises. The well equipped laboratory had mechanical shakers for the coarse and fine aggregate sieving operation, and washing and drying facilities. The average mass of the test portion was 10 kg. Washing procedures were carried out prior to the fine aggregate sieving operations.

The MTC construction technician obtained the road samples, which were also used for acceptance testing of the Granular A material. Road samples were tested by the same technician who obtained the samples. Testing was carried out in a well equipped MTC mobile laboratory. The average mass of the test portion was 8.6 kg. Washing procedures were carried out for all tests.

All samples obtained were split in half with one half of the sample being bagged and tagged for testing at Downsview. However, due to some omissions, some sample splits were not saved; as a result, 25 delivery and 36 road samples arrived at Downsview for testing (Figure 21).

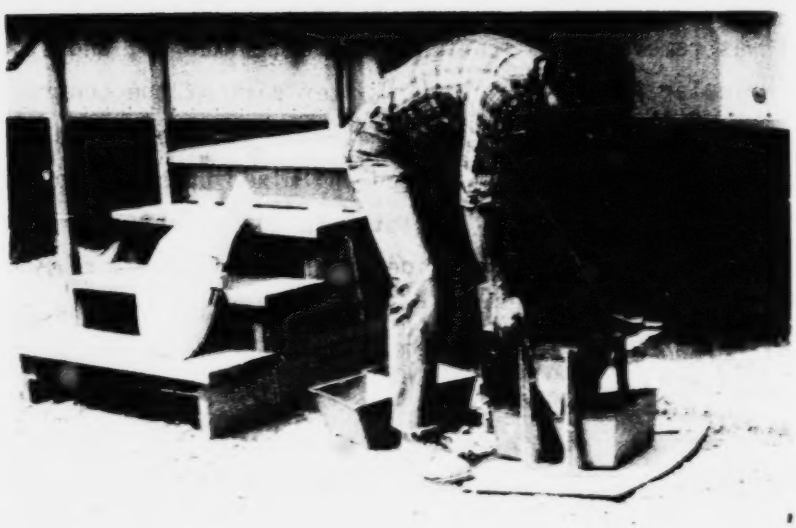


Figure 21 - Technician splitting sample in half for testing at Downsview

As mentioned earlier, the Granular A was produced and stockpiled by two different processes. Statistical analysis was carried out on each process separately, and also for the entire project. The conclusions were the same for both situations and, hence, for reasons of clarity, only the analysis for the entire project is given below.

6.3 Analysis and Evaluation of Test Results

Statistical analysis was carried out to determine the mean and standard deviation for each set of test data for comparison purposes. The four sets of samples that were analysed are given below:

1. Delivery samples obtained by the producer's technician, and tested in their laboratory (35 samples).

2. Road samples used for acceptance purposes, obtained and tested by MTC in its field laboratory at the contract (40 samples).

3. Delivery sample splits obtained by the producer, and tested in MTC's Downsview laboratory (25 samples).

4. Road sample splits obtained by MTC field staff, and tested in Downsview laboratory (36 samples).

Test results are presented again by normal distribution curves for each designated sieve in Figures 22 to 27 inclusive. Figure 28 shows the mean gradation of the sets of test data on a gradation chart.

6.4 Conclusion of the Analysis

In comparing the results of road samples and those of delivery samples, as tested by the Downsview laboratory, the following conclusion was reached:

- There is no significant difference in the mean, and there is no significant difference in variance.

The above conclusion indicates that there is no significant breakdown or segregation of material from when the trucks are loaded to when the material is placed on the road.

Comparisons of the test results obtained by Downsview laboratory and those obtained by both the producer's laboratory and MTC's field laboratory indicate all the laboratories and technicians involved had the same degree of precision and accuracy.

It should be noted that the material produced for this project was manufactured by two separate processes, and, for the purposes of this study, the separate processes were analysed as one. Hence, the overall material variation given for this project is substantially higher than is normally expected from this particular source.

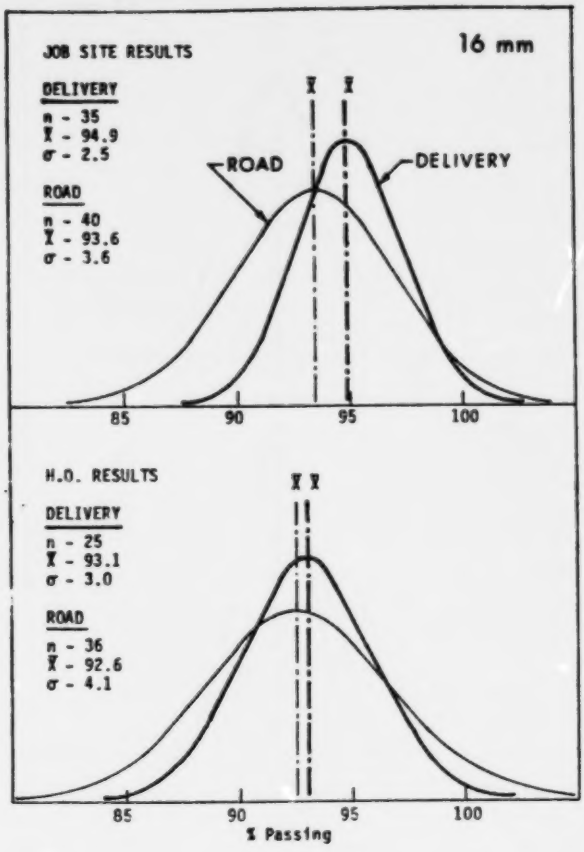


FIGURE 22

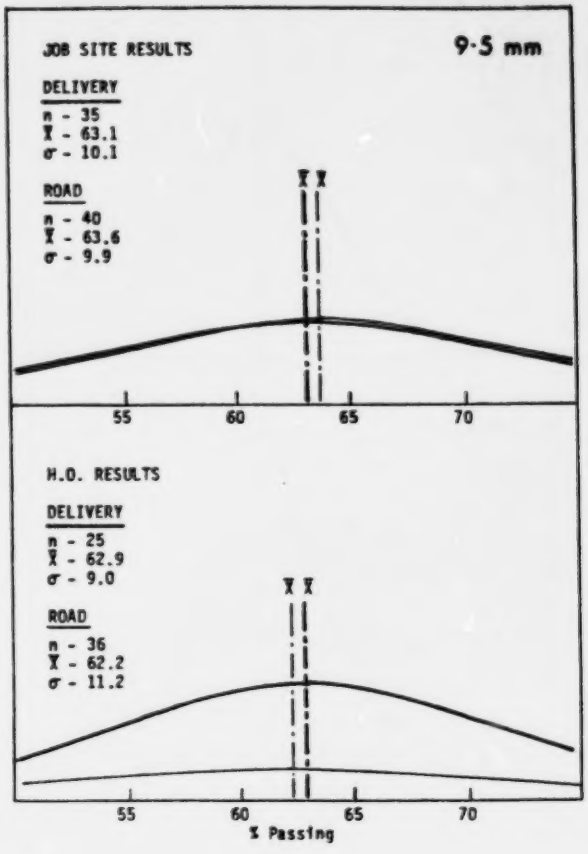


FIGURE 23

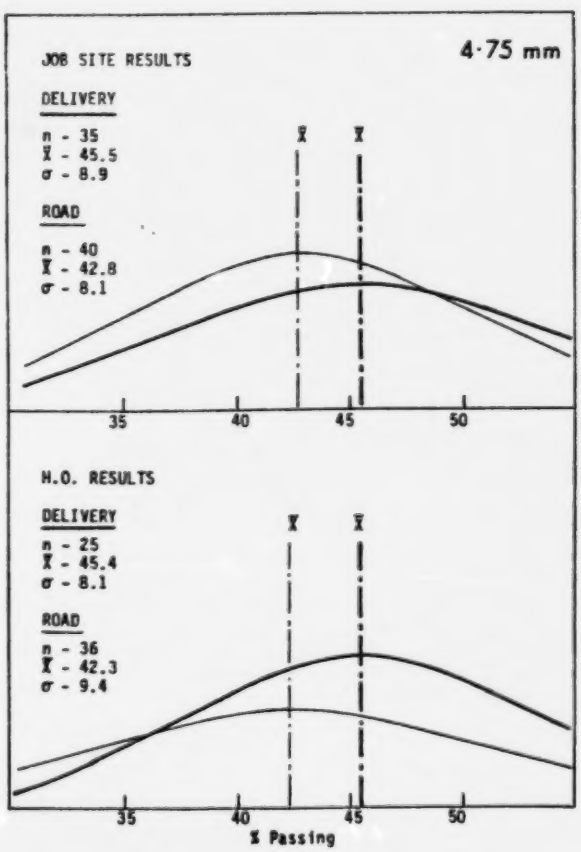


FIGURE 24

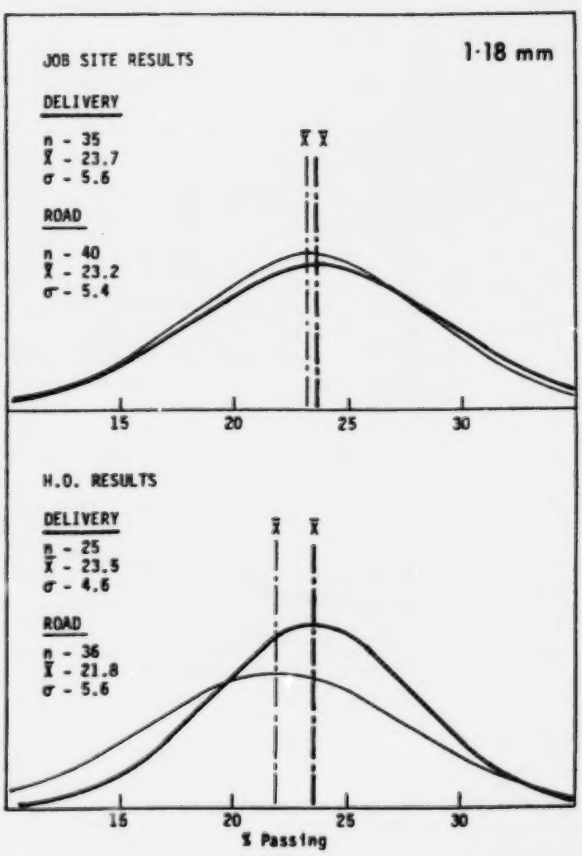


FIGURE 25

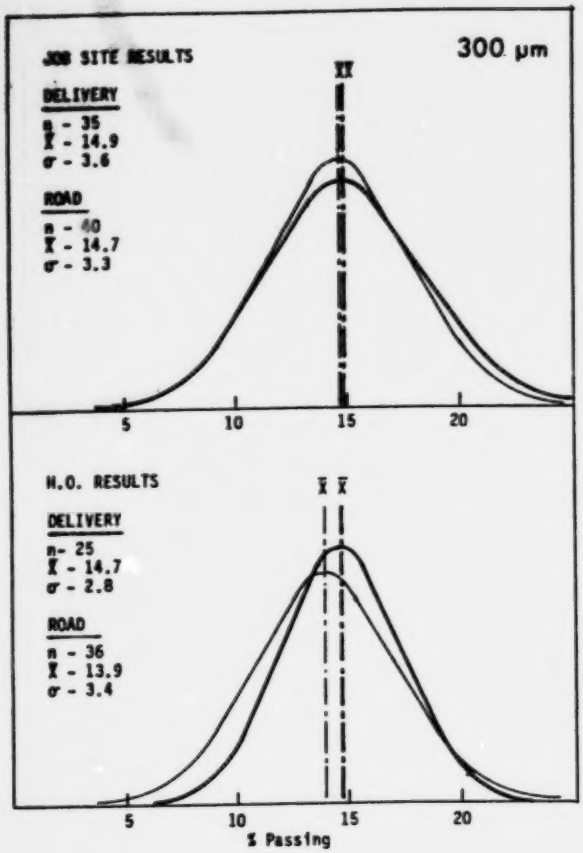


FIGURE 26

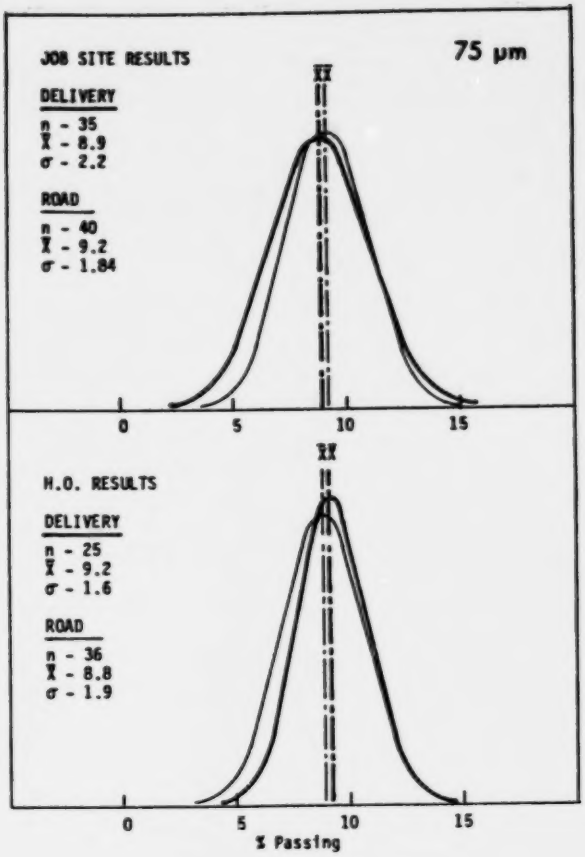
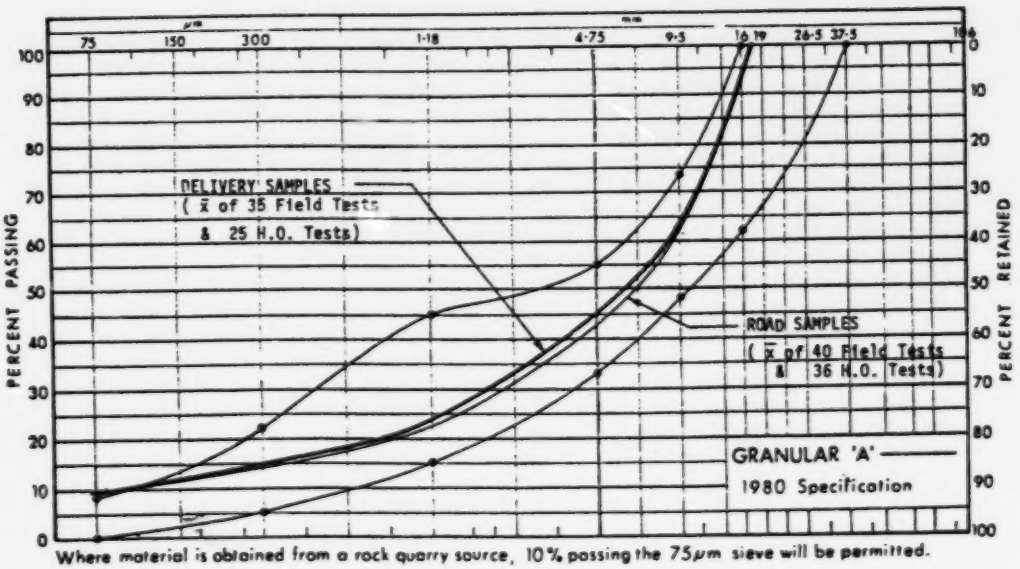


FIGURE 27

GRADATION SUMMARIES



Where material is obtained from a rock quarry source, 10% passing the 75µm sieve will be permitted.

FIGURE 28

7 Contract 81-67; Hwy. 401; Central Region

7.1 Production and Construction Data

Genstar was awarded this contract which had a tender quantity of some 309 000 tons of Granular A. The supply of this granular material was sub-contracted to T.C.G. Materials Limited, who obtained granular material from the McNally Pit (south of Hwy. 401, Puslinch Township, Concession II, Lot 26).

The crushing operations were subcontracted to three companies (Mann, Murray and Capital), each of whom brought in their own portable crushing units, and stockpiled their material separately. This study concentrated only on the material produced by the subcontractor Murray, which was used for Part A of Contract 81-67 (the widening of Hwy. 401 from 1 km west of Trafalgar Road, westerly 8.9 km).

During the early stages of production, the crushing operation continued twenty-four hours a day. Material from the pit face was transported to the crushing unit by a front end loader (Figure 29).

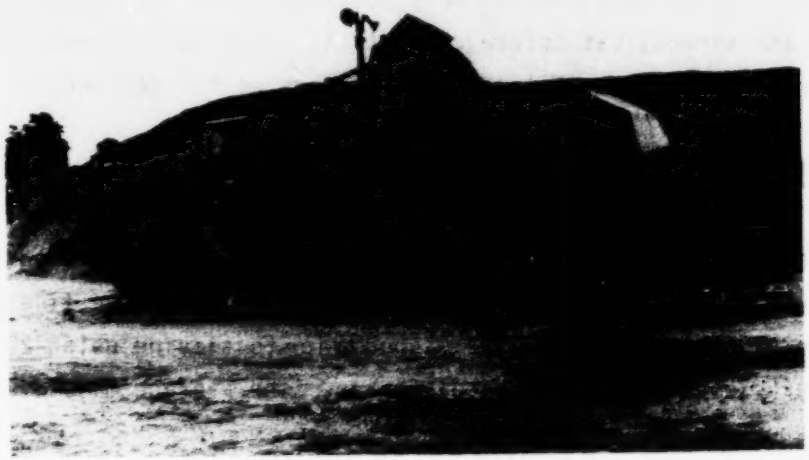


Figure 29 - Front end loader delivering material to portable crusher

After crushing, the material was transported by conveyor belt and stacking units to form a series of conical stockpiles. These conical piles were

levelled off by a small bulldozer to lifts 2 to 3 m thick. The delivery trucks were of the single and double bottom discharge type, having load capacities in the range of 23 to 36 t. Most of the trucks used were privately owned and operated. Genstar also owned and operated some of the trucks, as well as the front end loaders used at the pit for loading the delivery trucks and transporting material to the portable crushers.

The haul distance from the pit to the contract site is some 24 to 34 km, approximately 3 km on paved township and county roads, the remainder on Highway 401. Most of the delivery trucks were travelling at or near the speed limit of 100 km/h on the highway.

Acceptance sampling for this contract was carried out during production by obtaining material after the coned stockpiles were levelled off. The acceptance sampling and testing was performed by a technician from Trow Ltd. under contract to MTC for this purpose, who used the facilities of an M.T.C. mobile laboratory located at the M.T.C. Morriston Patrol Yard.

7.2 Sampling and Testing Program

A total of 32 delivery samples were obtained as the trucks were being loaded, and a total of 30 road samples were obtained after the material had been placed and spread, but before compaction. Road samples were taken generally from the same truck load that was sampled for delivery.

The technician from T.C.G. obtained two delivery samples each day, on a random time basis, and performed the gradation tests in their Aberfoyle Pit laboratory. The coarse aggregate tests were performed by hand sieving through 300 mm (12") diameter sieves using a rocker box. The fine aggregate portion of the test was always washed prior to sieving using 200 mm (8") diameter sieves and a mechanical shaker. The average mass of the sample test portion was 7.5 kg.

All road samples were obtained by an M.T.C. technician on a random area basis using random number tables to locate the length and offset within the spread load for the sample location. All samples were processed and tested in the M.T.C. mobile laboratory at the Morriston Patrol Yard.

The mobile lab was well equipped, having hydro, water, mechanical shakers,

a hot air drying oven and a microwave oven. All tests were performed using M.T.C. procedures. The average mass of the sample test portion was 7.6 kg.

As in the previous projects, all samples obtained were split in half with one half of the sample being bagged and tagged for testing in M.T.C. Head Office laboratory located at Downsview.

7.3 Analysis and Evaluation of Test Data

Statistical analysis was carried out to determine the mean and standard deviation for each set of test data for comparison purposes. The five sets of samples analysed are given below:

1. Delivery samples obtained by T.C.G. technician, and tested in their laboratory (32 samples).

2. Road samples obtained by a technician from M.T.C. Head Office, and tested in the mobile laboratory at the Morristown Patrol yard (30 samples).

3. Delivery sample splits obtained by T.C.G.'s technician, and tested in M.T.C. Head Office laboratory (32 samples).

4. Road sample splits obtained by M.T.C.'s technician, and tested in Head Office laboratory (30 samples).

5. Acceptance samples obtained and tested by Trow Ltd.'s technician from the stockpile as the material was being produced (132 samples).

Test results are presented again by normal distribution curves for each designated sieve in Figures 30 to 35 inclusively. Figure 36 shows the mean gradation for the previously mentioned sets of information.

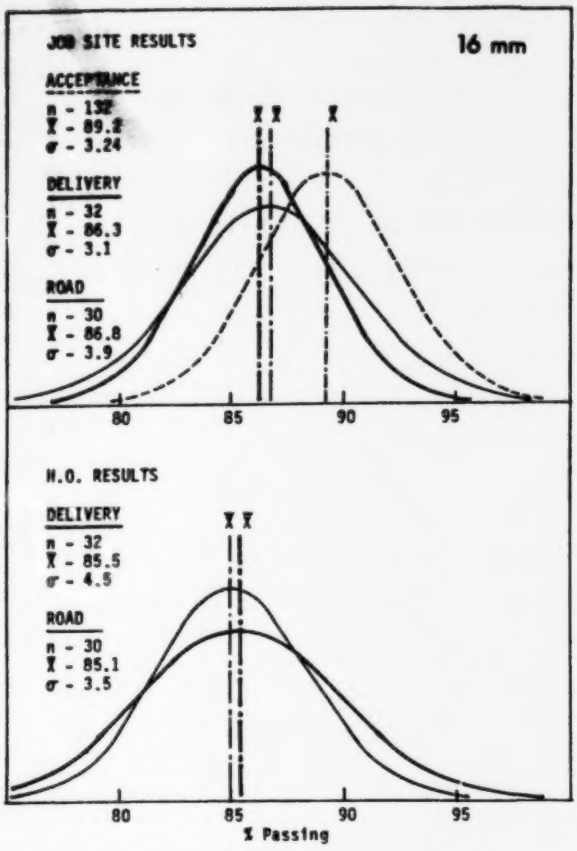


FIGURE 30

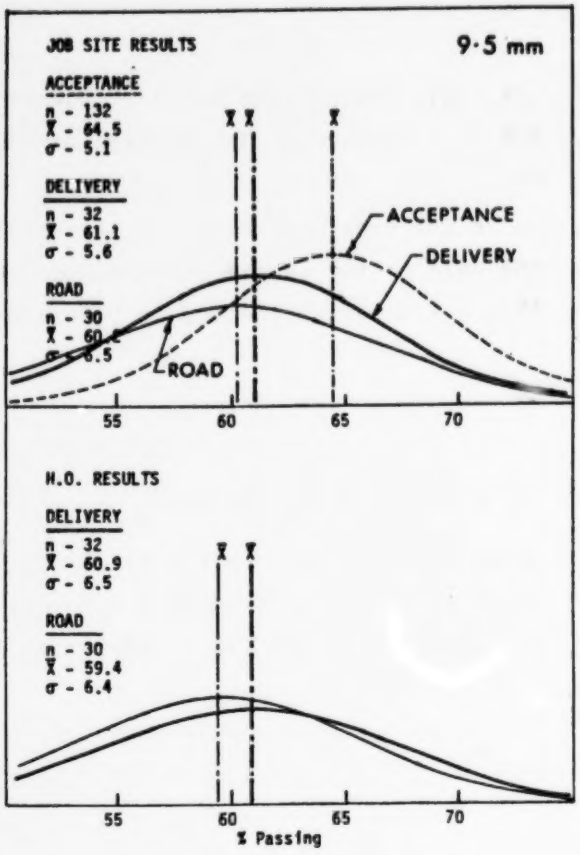


FIGURE 31

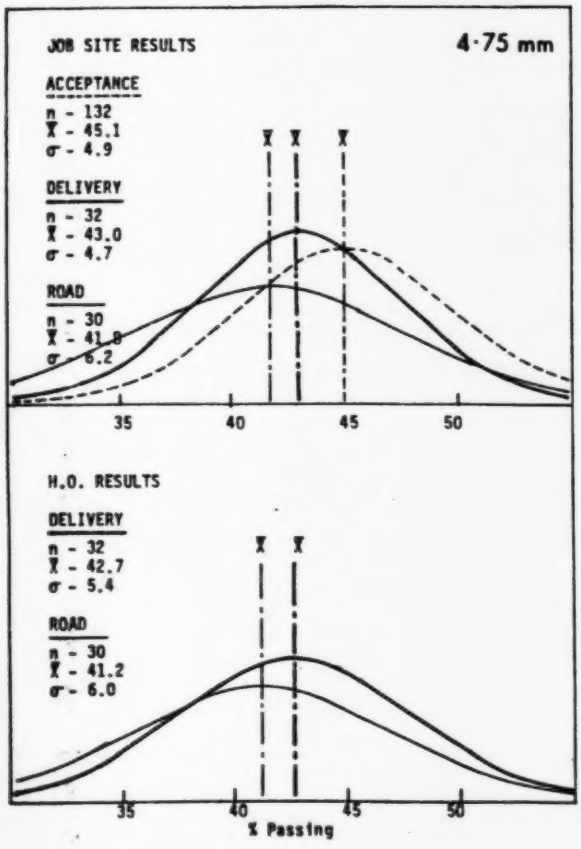


FIGURE 32

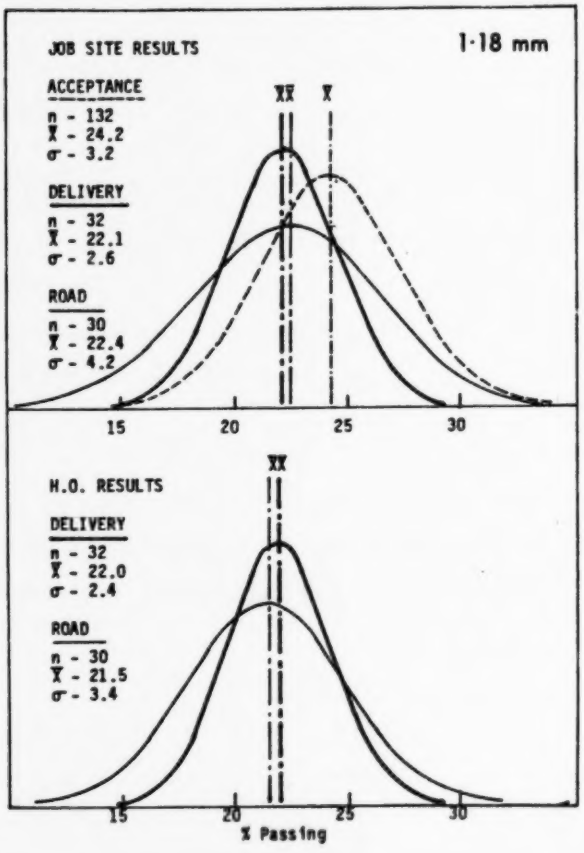


FIGURE 33

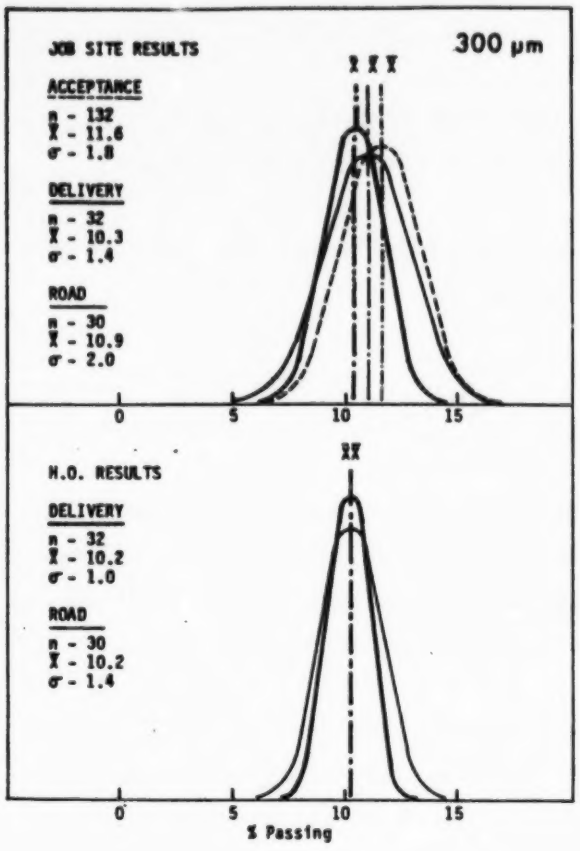


FIGURE 34

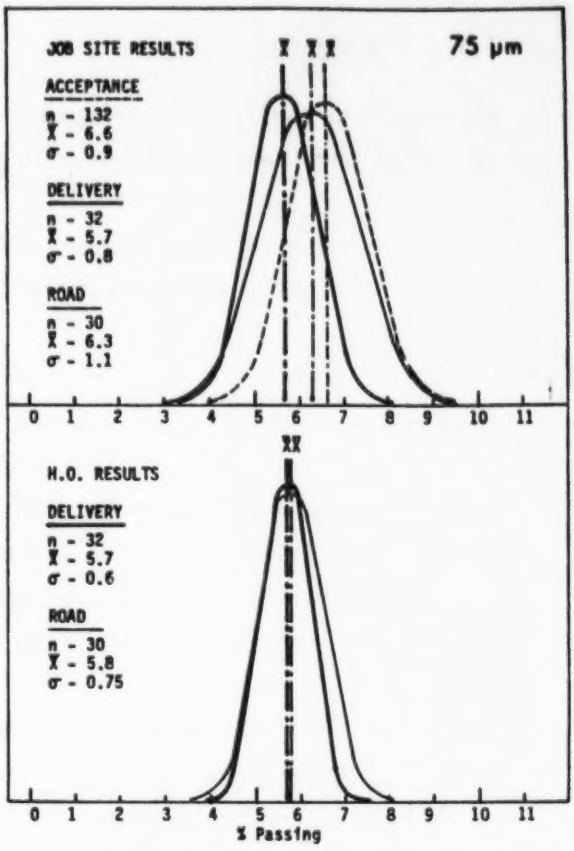


FIGURE 35

GRADATION SUMMARIES

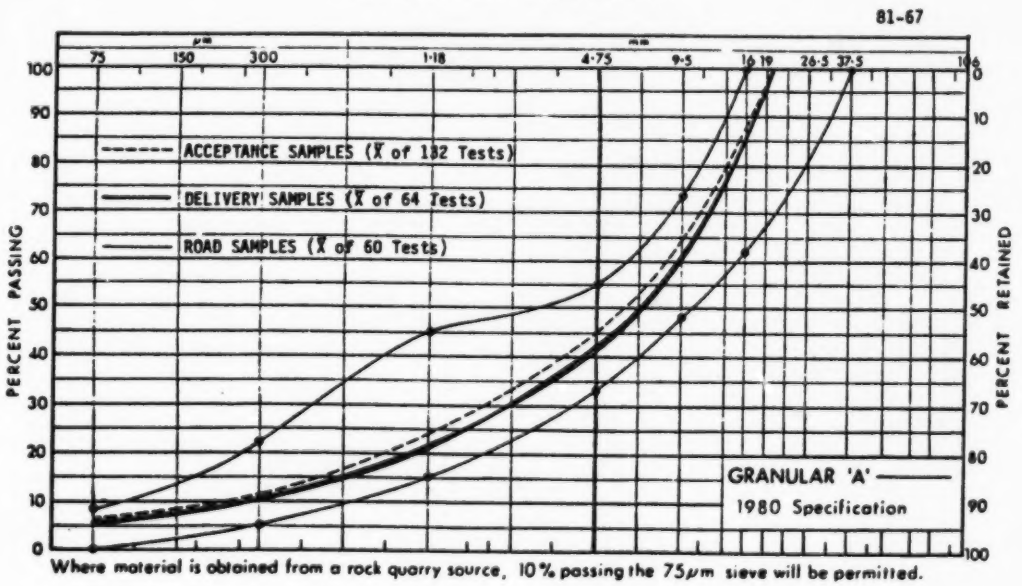

81-67
ACCEPTANCE SAMPLES (X̄ of 132 Tests)
DELIVERY SAMPLES (X̄ of 64 Tests)
ROAD SAMPLES (X̄ of 60 Tests)
GRANULAR 'A'
1980 Specification
PERCENT PASSING
PERCENT RETAINED
Where material is obtained from a rock quarry source, 10% passing the 75µm sieve will be permitted.

FIGURE 36

7.4 Conclusion of the Analysis

In comparing the results of road samples and those of delivery samples, as tested by the Downsview laboratory, the following conclusion was reached:

- There is no significant difference between the means, and there is no significant difference in the variance.

The above statement indicates that there is no significant breakdown or segregation of material during the loading, hauling and placing operation.

Comparisons were also made between the test results obtained by the Downsview laboratory and those obtained in the field by the T.C.G.'s technician and the M.T.C. technician. Analysis of these comparisons indicates that all of the laboratories involved had the same degree of precision and accuracy.

Analysis of the test results obtained for stockpile (acceptance samples compared to the test results obtained by the Downsview laboratory on the delivery and road samples indicate significant differences exist in the mean value and variance on the 9.5 mm, 4.75 mm and 1.18 mm sieves. The acceptance samples obtained during stockpiling indicate a finer material than the road and delivery samples. It is suggested that this difference is attributed solely to the bias associated with sampling into stockpile. In addition, the comparisons indicate some segregation has occurred during stockpiling operation since road and delivery samples tended to show more variation than the acceptance samples.

8 Contract 82-61; Hwy. 6N; Central Region

8.1 Production and Construction Data

The work on this contract required some 6.8 km of new construction, including hot mix paving, for the Caledonia By-Pass. The contract tender quantity required some 139 500 tons of Granular A to be placed to a depth of about 300 mm directly on the fill material. The contract documents included a Granular A Special Provision which incorporated a formal price adjustment schedule for material that was slightly out of specification.

Standard Paving, the contractor, elected to use Granular A produced by Haldimand Quarries, one of several aggregate sources of Standard Aggregates (a Division of Standard Industries Ltd.). The quarry is located on Highway 6 in the town of Hagersville, some 15 km south of Caledonia.

The quarry is being worked in two levels; the upper level is made up of the Bois Blanc cherty limestone formation; Granular A is produced from this source. The lower level is in the Bertie dolomite formation, which contains higher quality rock generally suitable for H.L. and concrete uses, as well as granular base and subbase. The primary crusher is a Cedar Rapids model, with a 1.2 x 0.9 m jaw. Aggregate from the primary crusher is delivered to a fully automated main plant by a 585 m long horizontal conveyor belt. The secondary crusher is a 1.2 m cone Symons, followed by two Symons cone tertiary crushers. The plant is able to switch from producing Granular A to clear stone and screenings very quickly. The stockpiling of Granular A is performed with a radial stacker than can travel and luff (Figure 37). A front end loader levels off the 'ridge' of aggregate daily.

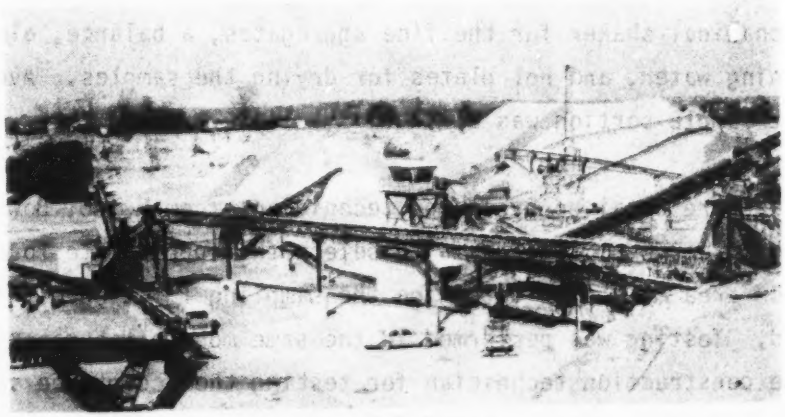


Figure 37 - Quarry operation, showing Granular A stockpile in background

Acceptance samples were taken during stockpiling operations, and were obtained by a technician from the M.T.C. construction staff. Four samples per day were obtained by sampling on a random time basis from the ridge of aggregate in a similar technique as used for delivery sampling. Testing was performed in a M.T.C. mobile laboratory located on the quarry property by the same technician who obtained the samples.

The delivery trucks were privately owned, and were mainly of the bottom discharge type having load capacities in the 23 to 36 t range. The trucks were loaded from the stockpile by front end loaders owned and operated by Haldimand Quarry. The trucks had a haul distance of 15 km along paved Highway 6 to reach the south end of the contract, and generally travelled at or near the maximum speed allowed.

8.2 Sampling and Testing Program

Due to the wet weather at the end of October and early November, 1982, the hauling and placing of Granular A was terminated earlier than expected. As a result of construction coming to a halt, it was possible to obtain only 14 delivery samples (taken during loading of the trucks) and 13 road samples (taken after the load was placed and spread, but before compaction). Delivery and road sampling times were selected independently on a random time basis.

Delivery samples were obtained by Haldimand's plant superintendent during the loading operations. Testing was performed in Haldimand's laboratory by their technician following M.T.C. testing procedures. The laboratory was equipped with a new mechanical shaker and splitter box for the coarse aggregate, a mechanical shaker for the fine aggregates, a balance, electrical power, running water, and hot plates for drying the samples. Average mass of the test sample portion was 8.1 kg.

Road samples were obtained by senior technicians from M.T.C. Downsview laboratory, using a random time basis to select the appropriate load to sample and a random area method to determine the sampling location within that spread load. Testing was performed in the same mobile laboratory trailer used by the construction technician for testing the acceptance samples. All testing was carried out following M.T.C. procedures; wash tests were performed on all fine aggregate test portions. The average mass of the sample test portion was 6.7 kg.

All road and delivery samples obtained were split in half with one half of the sample being bagged and tagged for testing in M.T.C.'s Head Office laboratory located in Downsview.

8.3 Analysis and Evaluation of Test Data

Statistical analysis was again carried out to determine the mean and standard deviation for each set of test data for comparison purposes. The five sets of samples analysed are given below:

1. Delivery samples obtained by Haldimand's Plant Superintendent, and tested in their laboratory (14 samples).

2. Road samples obtained by M.T.C.'s senior technicians, and tested in the M.T.C. field laboratory (13 samples).

3. Delivery sample splits obtained by Haldimand's Plant Superintendent and tested at M.T.C.'s Downsview laboratory (14 samples).

4. Road sample splits obtained by M.T.C. senior technicians, and tested at Head Office (13 samples).

5. Stockpile samples obtained during stockpiling operations by M.T.C.'s construction technician, and tested in M.T.C.'s laboratory located in the quarry (129 samples) (used for acceptance purposes).

Test results are presented by normal distribution curves for each designated sieve in Figures 38 to 43 inclusive. Figure 44 shows the mean gradation of the sets of test data on a gradation chart.

8.4 Conclusion of the Analysis

In comparing the test results of road samples and those of delivery samples, as tested at Head Office laboratory, the following conclusion was reached:

- There is no significant difference in the means, and there is no significant difference in variance.

The above conclusion indicates that there is no significant breakdown in the gradation of the material and no significant segregation of the material during the loading, haulage and placing operations.

Comparisons were made between the results obtained by the Downsview laboratory and those obtained in the field by Haldimand's technician and the M.T.C. technicians. Analysis of these comparisons indicate that all of the laboratories involved had the same degree of precision and accuracy.

Analysis of the test results obtained for acceptance samples compared to the Downsview laboratory test results for road and delivery samples indicate that there is no significant difference in variance, and that there is a significant difference in the means on the 1.18 mm, 300 um and the 75 um sieves. In reviewing the test results shown on the gradation chart (Figure 44), it is apparent that the acceptance samples obtained from the stockpile indicate a slightly coarser material than the road and delivery samples. It is suggested that this difference could be attributed to the test methods and procedures used. Hand sieving was used for all acceptance samples, and mechanical sieving was performed at the Downsview laboratory.

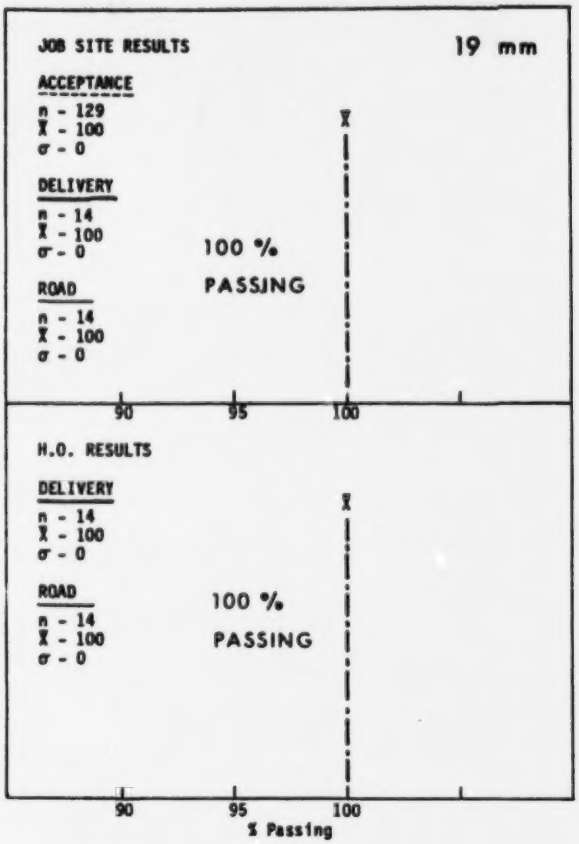


FIGURE 38

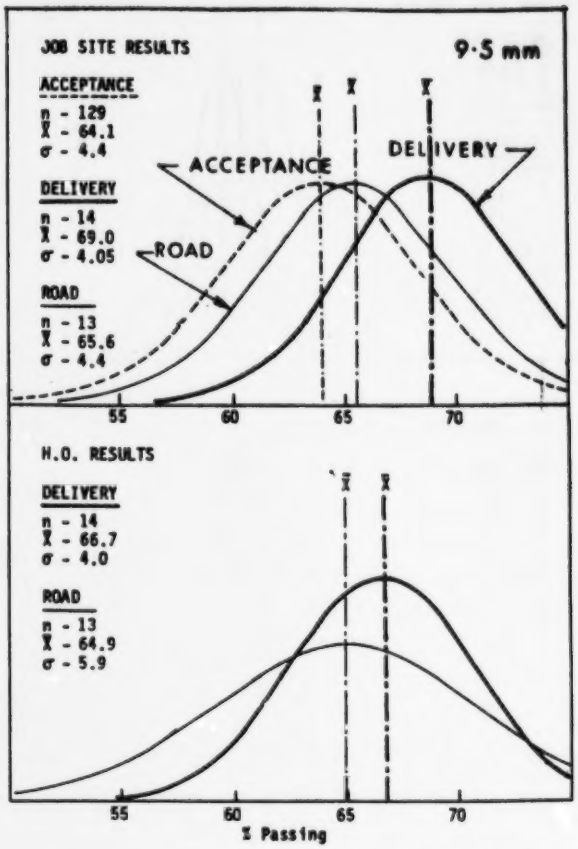


FIGURE 39

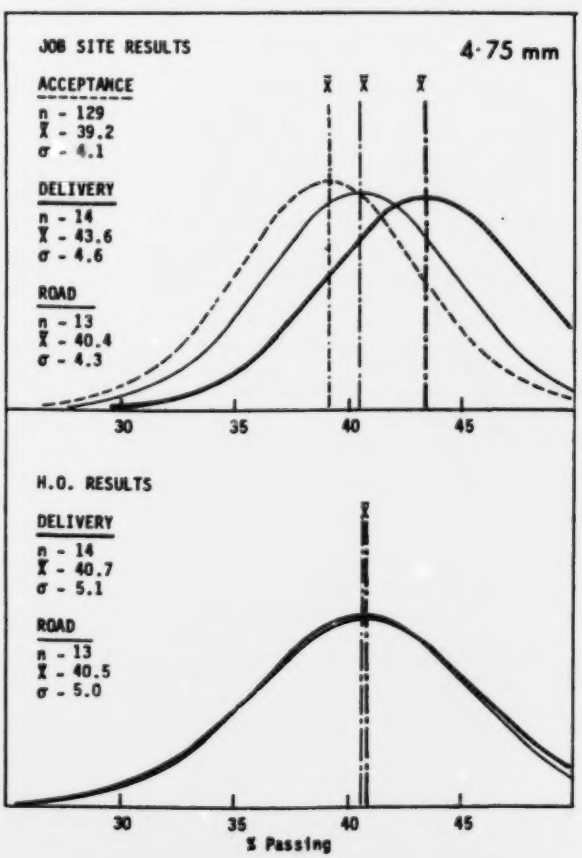


FIGURE 40

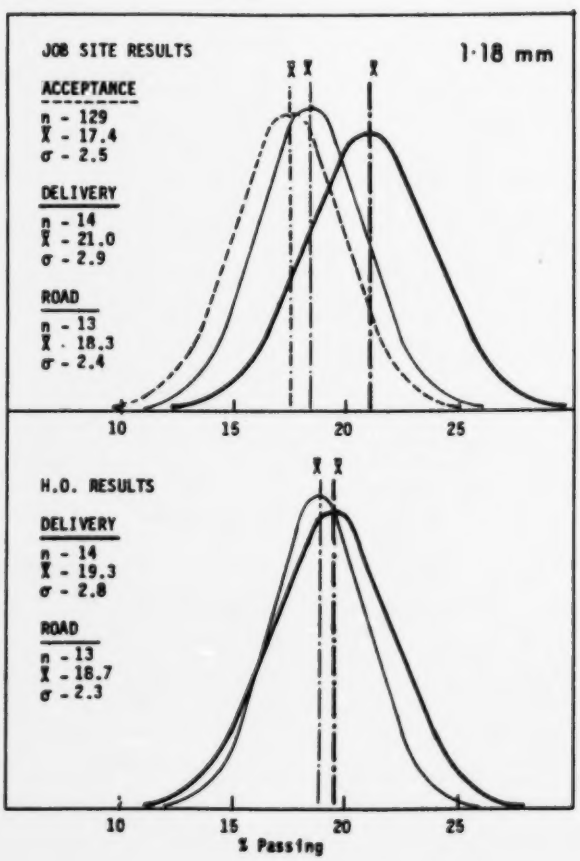


FIGURE 41

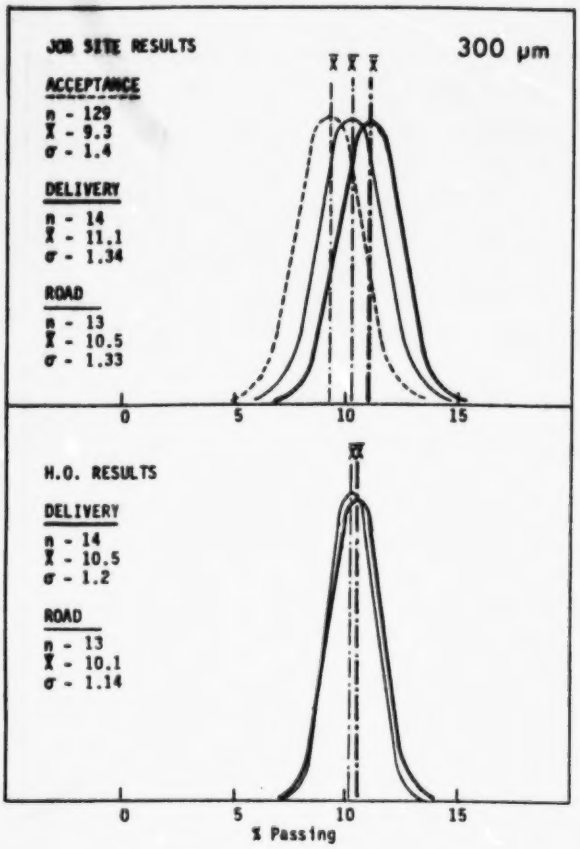


FIGURE 42

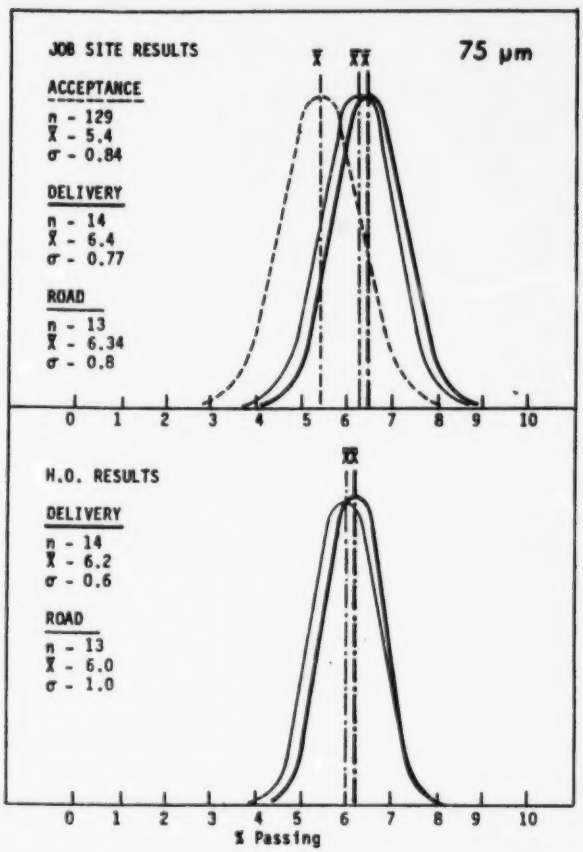


FIGURE 43

GRADATION SUMMARIES

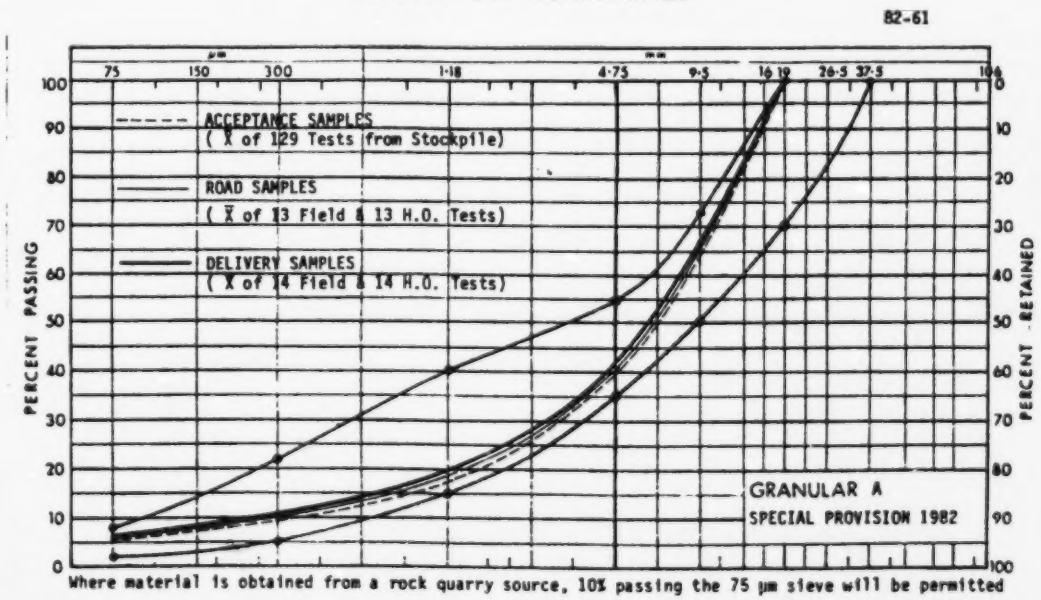

82-61
75 150 300 1·18 4·75 9·5 16 19 26·5 37·5
ACCEPTANCE SAMPLES
(X̄ of 129 Tests from Stockpile)
ROAD SAMPLES
(X̄ of 13 Field & 13 H.O. Tests)
DELIVERY SAMPLES
(X̄ of 14 Field & 14 H.O. Tests)
GRANULAR A
SPECIAL PROVISION 1982
PERCENT PASSING
PERCENT RETAINED
0 10 20 30 40 50 60 70 80 90 100
Where material is obtained from a rock quarry source, 10% passing the 75 µm sieve will be permitted

FIGURE 44

9 Discussion and Conclusion

This report has presented the findings of field studies conducted with the primary objective of determining if significant changes in gradation occur as a result of segregation or breakdown during the operations required to remove material from a stockpile, and place it on the road. The method of evaluating the extent of changes in gradation involved random sampling the material as it was loaded into the delivery vehicles, and also after it was placed on the road, but before compaction. Test results obtained by the M.T.C.'s Downsview laboratory on these two sets of samples were statistically compared to determine if significant variations in gradations occurred between the two points of sampling.

The five field studies represented the variety of production, stockpile construction and placement operations in common use for base coarse aggregates in Ontario. Two field studies encompassed quarry operations, while the remainder included either commercial or wayside gravel pit operations. Stockpile construction techniques included all of the common methods in use in Ontario today, each relying on some form of layer construction procedure. Placement operations included tailgating, spreader boxes and direct spreading from bottom discharge vehicles.

While not part of the initial objective of the project, the extent of sampling and testing was such that it was possible to compare the precision and accuracy of the various laboratories participating in the study. Indeed, as a result of the extensive testing and comparisons conducted, it was possible to evaluate the testing practices in common use.

In some projects where sampling and testing was conducted during stockpiling construction, it was possible to compare these test results with the road and delivery samples.

Our findings and conclusions are summarized as follows:

1. The testing of delivery and road samples will give the same results, provided random sampling is carried out using the same techniques as mentioned in this report. In view of this, it is suggested that future sampling for granular aggregates, where point-of-use sampling only is specified, be conducted either at delivery or on the road, using the methods outlined earlier in this report. In these instances, the choice of sampling at delivery or on the road should be

based on the practical and economic considerations for the particular project. It should be emphasized that the findings indicate that, if a producer can ensure that a product is within specifications as it leaves his plant out of stockpile, then that product should be within specifications after it is placed on the road.

2. Most of the laboratories involved, including those owned and operated by the producers, are capable of conducting sampling and testing in a fashion that gives the same degree of precision and accuracy as the MTC's Downsview laboratory. Where differences exist, it is usually attributable to the type of equipment in use and/or the operator's inexperience.

3. The test results on samples obtained as the stockpiles were built did not compare well, in most cases, with the test results on the delivery or road samples. No apparent trend was observed; in some projects, the stockpile samples were consistently coarser, whereas in others, the stockpile samples were consistently finer than the road samples. Since the program was not set up to evaluate this aspect, the reasons for the discrepancies can only be postulated. It is suggested that the differences are a result of the method of sampling and/or stockpiling procedures during the production of granular materials.

   This finding leads one to question the reliability of sampling during the stockpile construction. It is suggested that, prior to instituting universal road sampling, the Ministry investigate further this aspect, and develop a practice that would, under given stockpile construction methods, provide agreement with the road/delivery samples. (Note: this will be a subject of another study now underway.)

4. In the course of the investigations, it became apparent that certain test procedures and equipment are essential to ensure the reliability of the gradation test. These are outlined in the following paragraphs:

   a) In order to obtain the desired level of confidence in the test results, each field sample must contain a sufficient mass of material. The size of field samples depends on the maximum particle size of the material, and should be based on ASTM Standard D 75-82. The sample masses are shown on page 6 of MTC Report EM-67.

b) In the laboratory, the field sample should be reduced to test portion sizes by use of a mechanical sample splitter conforming to ASTM Standard C 702-75. The minimum test portion masses are shown on page 6 of MTC Report EM-67 and in MTC Test Method LS 602.

c) The mass of fine aggregates (passing 4.75 mm) for the sieve analysis should weigh, after drying, approximately 250 g. If the fine aggregate portion of the sample is very uniformly graded, the test portion for washing may be reduced to 125 g, to prevent overloading on any sieve.

d) The reliability of hand sieving techniques is largely dependent on the experience and care taken by the testing technician. To reduce operator bias, testing should be conducted using mechanical shakers equipped with additional separator sieves between the specific sieves to prevent overloading. Shaking times should be controlled to 8 minutes.

e) There is a probability of particle loss during sieving, which may result in testing errors. The particle loss may be minimized by ensuring that the shaking device is anchored securely and is level. To check the particle loss, the total mass of aggregate before and after sieving should be determined by weighing. If the difference is more than 1%, then the equipment and procedure should be checked and corrected.

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